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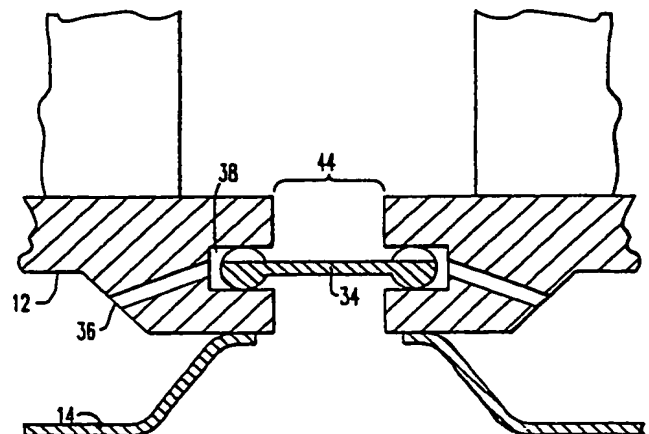
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(54) **Gas turbine with film cooling of turbine vane shrouds.**

(57) In a gas turbine having an inner shroud portion (12) at each of the radially inboard ends of its stationary vanes (10) and edges (50) at the circumferential ends of the shrouds (12) and a circumferential gap (44) between adjacent shroud portions with a seal strip (34) disposed therebetween and a radial barrier (16) extending circumferentially around, and projecting inwardly from, the shroud so as to define a shroud cavity (24), each of the seal strips (34) has two longitudinal edges with sealing surfaces formed along said longitudinal edges and residing in slots (38) formed in the adjacent inner shrouds (12) so as to span the circumferential gap (44); and a plurality of intermittent reliefs (42) are formed in each of the sealing surfaces for controlled leakage.

FIG. 4



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GAS TURBINE WITH FILM COOLING OF TURBINE VANE SHROUDS

The present invention generally relates to gas turbines. More specifically, the present invention relates to an apparatus and method for supplying film cooling to the inner shrouds of the turbine vanes.

To achieve maximum power output of the turbine it is desirable to operate with as high a gas temperature as feasible. The gas temperatures of modern gas turbines are such that without sufficient cooling the metal temperature of the flow section components would exceed those allowable for adequate durability of the components. Hence, it is vital that adequate cooling air be supplied to such components. Since to be effective such cooling air must be pressurized, it is typically bled off of the compressor discharge airflow thus bypassing the combustion process. As a result, the work expended in compressing the cooling air is not recovered from the combustion and expansion processes. It is, therefore, desirable to minimize the use of cooling air to obtain maximum thermodynamic efficiency, and the effective use of cooling air is a key factor in the advancement of gas turbine technology. The present invention concerns the supply and control of film cooling air to the inner shrouds of the turbine vanes.

The hot gas flow path of the turbine section of a gas turbine is comprised of an annular chamber contained within a cylinder and surrounding a centrally disposed rotating shaft. Inside the annular chamber are alternating rows of stationary vanes and rotating blades. The vanes and blades in each row are arrayed circumferentially around the annulus. Each vane is comprised of an airfoil and inner and outer shrouds. The airfoil serves to properly direct the gas flow to the downstream rotating blades. The inner and outer shrouds of each vane nearly abut those of the adjacent vane so that, when combined over the entire row, the shrouds form a short axial section of the gas path annulus. However, there is a small circumferential gap between each shroud. Generally high pressure air is present in the annular cavity formed by the inner surface of the inner shrouds. This is so in the first vane row because it serves as the entrance to the turbine section and hence is immediately connected to a plenum chamber containing compressor discharge air awaiting introduction into the combustion system. As a result of this arrangement high pressure compressor discharge air fills the cavity formed between the inner shrouds of the first row vanes and the outer surface of the housing which encases the shaft in this vicinity. In the vane rows downstream of the first row a somewhat different situation exists. To cool the rotating discs of the

blade rows immediately upstream and downstream of the vane row, cooling air is supplied to the cavity formed by the inner shrouds and the faces of the adjacent discs.

Leakage of the high pressure air in these cavities into the hot gas flow results in a loss of thermodynamic performance. Hence means are employed to restrict such leakage. Since the pressure of the hot gas flow drops as it traverses downstream through each succeeding row in the turbine, the natural tendency of the high pressure air in these cavities is to leak out of the cavity by flowing downstream through the axial gap between the trailing edge of the inner shroud and the rim of the adjacent rotating disc. This is prevented by a radial barrier extending circumferentially around the annular cavity. In the first vane row this barrier comprises a support rail, emanating radially inward from the inner shroud inner surface, which serves to support the vane against the housing encasing the shaft. Although a hole may be provided in the support rail allowing high pressure air to flow across it, a containment cover affixed to the inner surface of the inner shroud prevents the high pressure air from entering the shroud cavity downstream of the barrier. In rows downstream of the first row, the barrier comprises a similar support rail to which is affixed an interstage seal.

A second potential leakage path of the high pressure air in the shroud cavity is through the circumferential gaps between adjacent inner shrouds. In the past such leakage has been prevented by strip seals disposed in slots in the edges of the inner shrouds forming the gaps. In earlier turbine designs leakage past these seals resulted in a thin film of cooling air flowing over the outer surface of the inner shroud. This film cooling was sufficient to prevent overheating of the inner shrouds. However, as advances in gas turbine technology allow increasingly higher hot gas temperatures, it may be anticipated that the leakage past the seals will become insufficient, especially in the portion of the shroud downstream of the radial barrier, where the pressure of the air, and hence the leakage rate, is lower. In such advanced turbines overheating can occur on the first vane row in the portion of the inner shroud downstream of the radial barrier if adequate cooling is not provided. Since overheating of the shroud will cause its deterioration through corrosion and cracking, it results in the need to replace the vanes more frequently, a situation which is costly and renders the turbine unavailable for use for substantial periods.

It is therefore desirable to provide an apparatus

and method which will achieve adequate film cooling of the inner shrouds in areas, such as downstream of the radial barrier, where the pressure of the air within the shroud cavity is low.

It is the principal object of the present invention to provide an arrangement which insures sufficient film cooling the portion of the inner shroud not supplied with high pressure cooling air in a regulated manner.

With this object in view, the present invention resides in a gas turbine of the type having a turbine cylinder containing alternating arrays of stationary vanes and rotor blades, disposed in an annular flow path, each of said vanes having a radially inboard end, there being an inner shroud portion at each of said radially inboard ends; each of said inner shrouds having first and second edges at its circumferential ends, said edges of each pair of adjacent inner shroud portions forming a circumferential gap; with a seal strip disposed therebetween and a radial barrier extending circumferentially around and projecting inwardly from said shroud so as to define a shroud cavity, said radial barrier restricting the flow of high pressure air supplied to said shroud cavity, characterized in that each of said seal strips has two longitudinal edges with sealing surfaces formed along said longitudinal edges and residing in slots formed in adjacent ones of said inner shrouds so as to span said circumferential gap; and that a plurality of intermittent reliefs are formed in each of said sealing surfaces, the size and quantity of which being selected depending on the leakage flow desired.

The invention will become more readily apparent from the following description of a preferred embodiment thereof shown, by way of example only, in the accompanying drawings, wherein:

Figure 1 is a longitudinal cross-section of the turbine section of a gas turbine;

Figure 2 shows a portion of the longitudinal cross-section of Figure 1 in the vicinity of the first row vanes;

Figure 3 is a cross-section taken through line 3-3 of Figure 2 showing the inner shrouds of two adjacent vanes;

Figure 4 is a cross-section of the inner shroud taken through line 4-4 of Figure 2;

Figure 5 is a perspective view of the strip seal.

Referring to the drawings, wherein like numerals represent like elements, there is illustrated in Fig. 1 a longitudinal section of the turbine portion of a gas turbine, showing the turbine cylinder 48 in which are contained alternating rows of stationary vanes and rotating blades. The arrows indicate the flow of hot gas through the turbine. As shown, the first row vanes 10 form the inlet to the turbine. Also shown are portions of the chamber 32 containing

the combustion system and the duct 22 which directs the flow of hot gas from the combustion system to the turbine inlet. Figur 2 shows an enlarged view of a portion of the turbine section in the vicinity of the first row vanes 10. As illustrated, the invention applies preferably to providing cooling the first row of shrouds, but is applicable to the other rows as well. At the radially outboard end of each vane is an outer shroud 11 and at the inboard end is an inner shroud 12. Each inner shroud has two approximately axially oriented edges 50 and front and rear circumferentially oriented edges. A plurality of vanes 10 are arrayed circumferentially around the annular flow section of the turbine. The inner and outer shroud of each vane nearly abut those of the adjacent vane so that, when combined over the entire row, the shrouds form a short axial section of the gas path annulus. However, there are small circumferential gaps 44 between the approximately axially oriented edges 50 of each inner shroud and the adjacent inner shrouds, as seen in Figure 4. A housing 20 encases the rotating shaft in the vicinity of the first row vanes. Support rails 16 emanating radially inward from each inner shroud support the vane against this housing.

High pressure air from the discharge of the compressor flows within the chamber 32 prior to its introduction into the combustion system. This high pressure air flows freely into a shroud cavity 24 formed between the inner surface of inner shrouds 12 and the shaft housing 20. Rotating blades 28 are affixed to a rotating disc 30 adjacent to the vanes. A gap 46 is formed between the downstream edge of the shroud 12 and the face of the adjacent disc 30. The support rails 16 provide a radial barrier to leakage of the high pressure air downstream by preventing it from flowing through the shroud cavity 24 and into the hot gas flow through the gap 46.

Referring to Figures 2-5, it is seen that hot gas 26 from the combustion system flows over the outer surfaces of the inner shrouds. Leakage of the high pressure air into this hot gas flow through the gaps 44 between shrouds is prevented by means of strip seals 34 of dumbbell-shaped cross section shown in Figures 4 and 5. There is one strip seal for each gap, the seal spans the gap and is retained in the two slots along the edges of adjacent shrouds forming the gap. The cylindrical portions 40 of the dumbbell shape run along the two longitudinal edges of the seal and reside in the slots 38. Since the diameter of the cylindrical portions is only slightly smaller than the width of the slot they provide a sealing surface.

Holes 18 are provided in the support rail 16, one hole for each inner shroud. The holes extend from the front to the rear face of the rail and are equally spaced circumferentially around the rail. A

containment cover 14 affixed to the inner surface of the inner shroud allows high pressure air to flow through these holes in the support rail and into the vane airfoil through an opening 15 in the inner shroud. The containment cover extends axially from the rear face of the support rail to near the rear circumferentially oriented edge of the shroud and circumferentially it approximately spans the two edges forming the gaps, as shown in Figure 3.

The portion of the shroud cavity 25 downstream of the support rail 16 is not supplied with high pressure air from the compressor, as a result of being sealed off from chamber 32 by the support rail 16. Hence under the prior art approach very little cooling air can be expected to leak past the strip seal 34 to cool the portion of the inner shroud downstream of the support rail. In accordance with the present invention a means is provided for distributing high pressure air to the gap downstream of the support rail by providing a plurality of holes 36 extending from the slots 38 to the inner surface of the inner shroud encompassed by the containment cover 14 as shown in Figure 4. These holes allow the containment cover to act as a manifold so that the holes 18 in the support rail 16 can supply high pressure air to the slots containing the seal 34. In accordance with another feature of the invention, a means is provided for regulating and distributing the leakage through the seal by providing intermittent reliefs 42 in the cylindrical portions 40 of the seal 34 downstream of the radial barrier, as shown in Figure 5, the size and quantity of which determine the amount of leakage. The amount of leakage flow provided in this manner can also be controlled by varying the size of the holes 18 in the support rail 16. This leakage of high pressure air past the seals and through the circumferential gap between inner shrouds provides a film of air which flows over the outer surface of the inner shroud, thereby cooling it.

Claims

1. A gas turbine of the type having a turbine cylinder (48) containing alternating arrays of stationary vanes (10) and rotor blades (28), disposed in an annular flow path, each of said vanes (10) having a radially inboard end, there being an inner shroud portion (12) at each of the radially inboard ends; each of said inner shrouds (12) having first and second edges (50) at its circumferential ends, said edges (50) of each pair of adjacent inner shroud portions forming a circumferential gap (44); with a seal strip (34) disposed therebetween and a radial barrier (16) extending circumferentially around, and projecting inwardly from, said shroud so as to define a shroud cavity (24), said radial barrier

(16) restricting the flow of high pressure air supplied to said shroud cavity (24), characterized in that each of said seal strips (34) has two longitudinal edges with sealing surfaces formed along said longitudinal edges and residing in slots (38) formed in adjacent ones of said inner shrouds (12) so as to span said circumferential gap (44); and that a plurality of intermittent reliefs (42) are formed in each of said sealing surfaces, the size and quantity of which being selected depending on the leakage flow desired.

2. A gas turbine according to claim 1, characterized in that each of said strip seals (34) comprises a dumbbell-shaped cross-section having cylindrical portions (40), each of said cylindrical portions (40) extending the length of each of said seals (34), the diameter of said cylindrical portions (40) being approximately that of the width of said slots (38), thereby forming said sealing surfaces.

3. A gas turbine according to claim 1 or 2, characterized in that holes (36) are provided in each of said inner shrouds (12) extending from said inner surface to said slot (38) in said first edge (50) and from said inner surface to said slot (38) in said second edge (50); and holes (18) in said radial barrier (16), extend from said forward to said rear face of said barrier (16); and that each of said inner shrouds (12) has a manifold (14) providing for communication between said holes (18) in said radial barrier (16) and said holes (36) in its respective inner shroud (12).

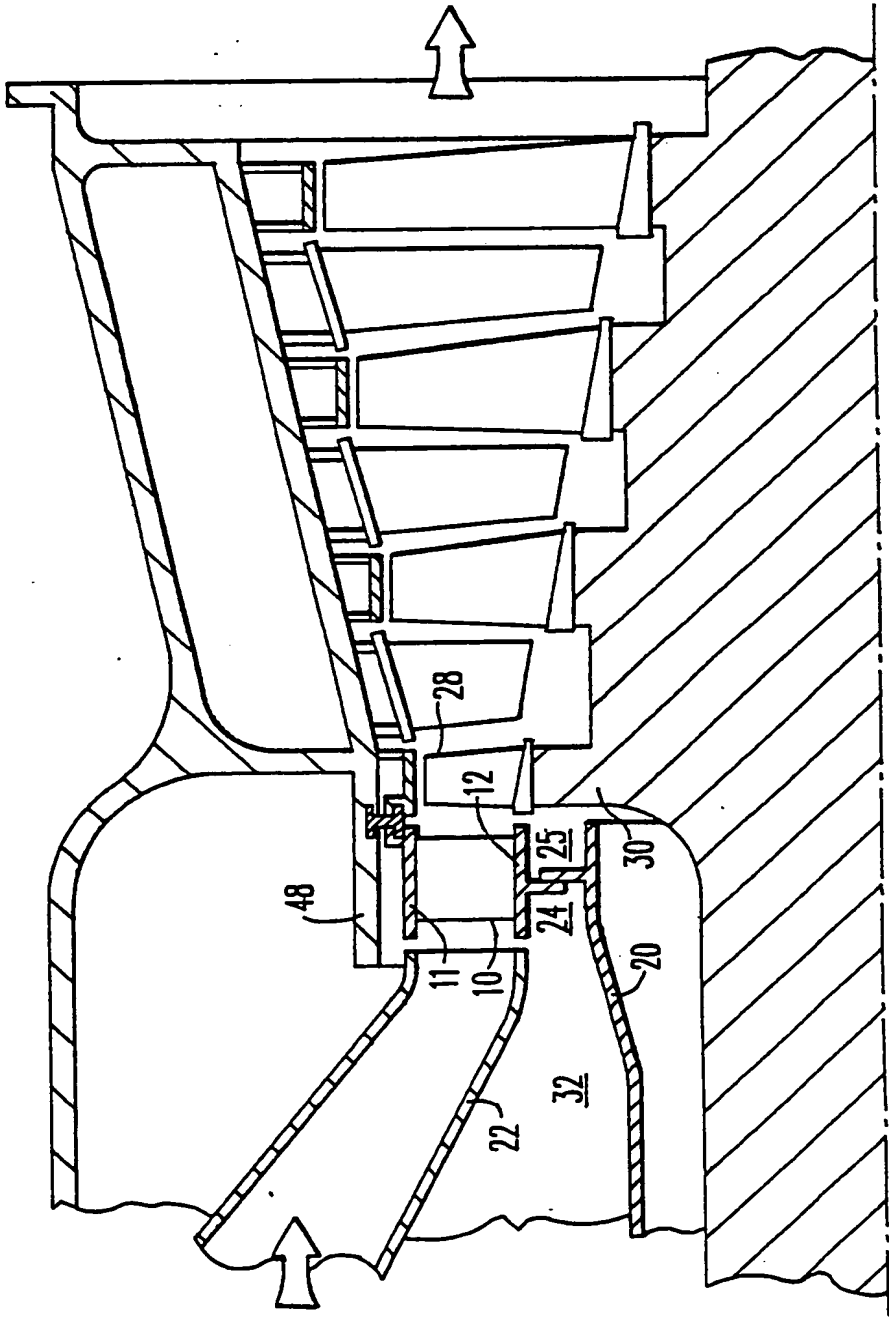


FIG.1

FIG. 2

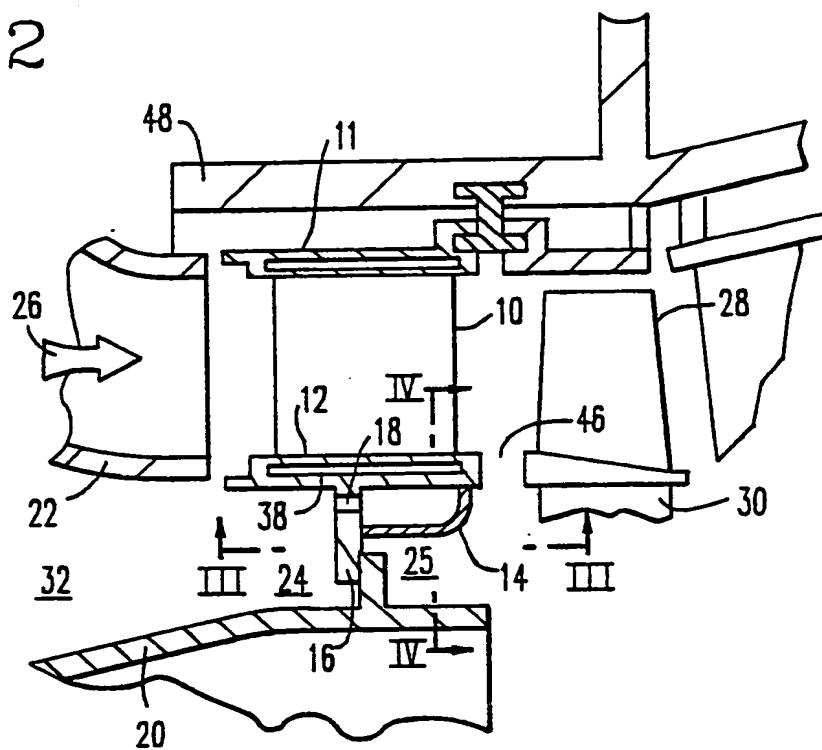


FIG. 3

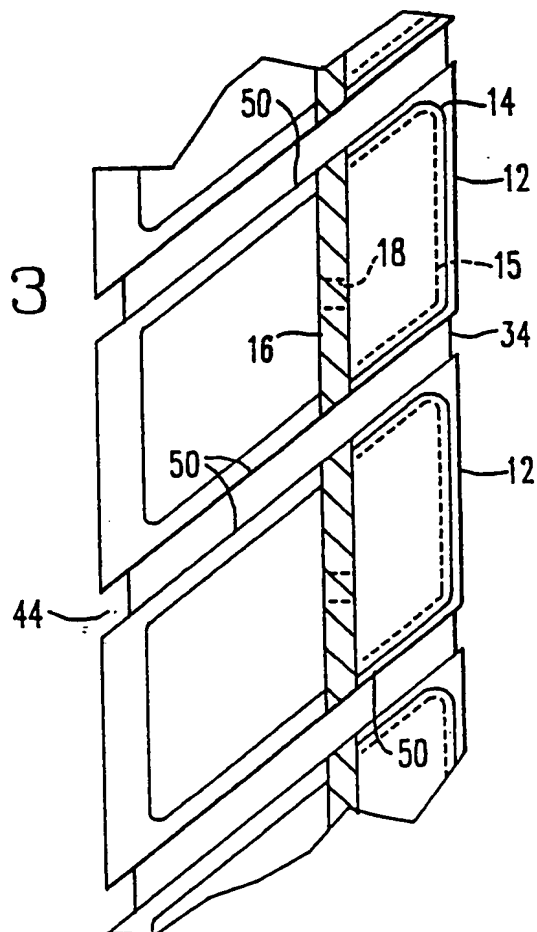


FIG. 4

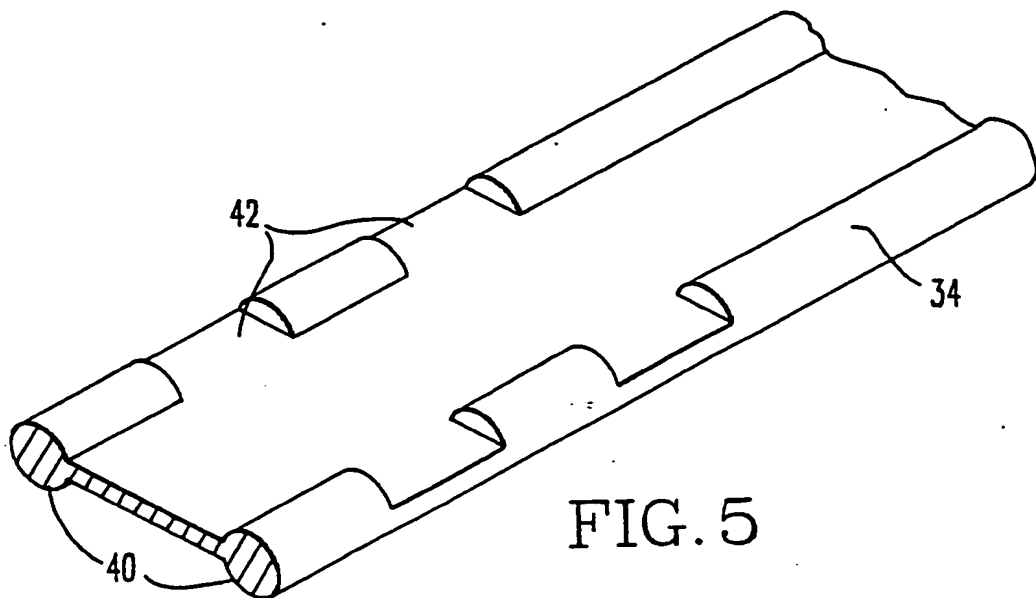
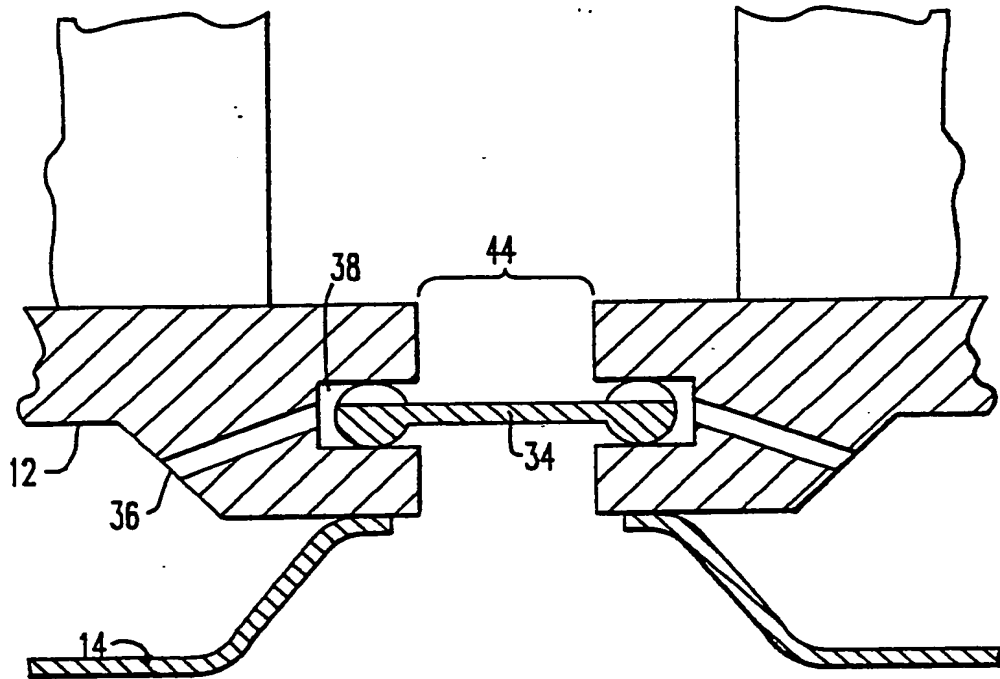


FIG. 5



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EUROPEAN SEARCH REPORT

Application Number

EP 89 11 4666

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	GB-A-1 580 884 (ROLLS-ROYCE) * Whole document *	1-3	F 01 D 11/00 F 01 D 9/04 F 02 C 7/28
Y	GB-A-2 195 403 (ROLLS-ROYCE) * Whole document *	1-3	
A	FR-A-2 359 976 (GENERAL ELECTRIC) * Page 5, line 35 - page 6, line 22; figures 1-5 *	3	
A	US-A-3 182 955 (HYDE) * Whole document *	3	
A	DE-A-1 928 182 (WESTINGHOUSE) * Page 6, lines 7-10; figures 2,4 *	1,2	
A	FR-A-1 097 531 (ROLLS-ROYCE) * Figures 1,7 *	3	
A	GB-A- 761 380 (POWER JETS) * Page 2, lines 119-129; figure 2 *	3	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F 01 D F 02 C
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 27-11-1989	Examiner CRIADO Y JIMENEZ F.A.
CATEGORY OF CITED DOCUMENTS			
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